Lockheed Martin
Response Engineering Analytical Contract
2890 Woodbridge Avenue Building 209 Annex
Edison, NJ 08837-3679
Telephone 732-321-4200 Facsimile 732-494-4021

LOCKHEED MARTIN

DATE: July 16, 2009

TO: Mark Sprenger, EPA / ERT, Work Assignment Manager

THROUGH: Larry Lyons, REAC Task Leader
Dennis Miller, REAC Program Manager

FROM: Martin Ebel, REAC Geophysicist ME

SUBJECT: Technical Memorandum
Geophysical Survey, Raritan Bay Slag -Work Assignment #0-356

## INTRODUCTION

Geophysical surveys were performed at the Raritan Bay Slag Site by Lockheed Martin personnel, under the Response Engineering and Analytical Contract (REAC) to the Environmental Protection Agency / Environmental Response Team (EPA/ERT) on April 4, May 11 and 28, and June 8, 2009. The objectives of the surveys were to determine the presence and extent of slag fill material and the thickness of the fill at the Old Bridge Waterfront Park and the beach adjacent to the park. Three areas, totaling approximately six acres, were surveyed. The areas, depicted in Figure 1, are designated as Area A, incorporating the beach adjacent to the park, Area B, the playground, and Area C, the walkway area east of the playground.

## SURVEY METHODS

Three methods were employed to survey the site, including ground penetrating radar (GPR), frequency-domain electromagnetic (FDEM) terrain conductivity, and electrical imaging (EI).

### *Ground Penetration Radar (GPR)*

The GPR system used in this survey was a Sensors and Software® Smartcart Noggin with a 250 megahertz antenna. A GPR system transmits radar waves into the ground and records reflections of the waves from subsurface interfaces, and builds a cross-section based on these reflections. A discrete object, such as an underground pipe, produces a parabola as the GPR approaches, passes over and moves away from the object. Fill material containing boulders or slag typically produces multiple, overlapping parabolas.

### *Frequency-Domain Electromagnetics (FDEM) Terrain Conductivity Survey*

A Geonics® EM31 MK2 (EM31) instrument was used to conduct the FDEM terrain conductivity survey. The instrument, carried by a single operator from a shoulder harness, can be triggered manually to take a measurement or set to trigger automatically at fixed time increments. The EM31 has a 12-foot long boom to separate the transmitter and receiver coils that set up the electromagnetic (EM) dipole. The transmitter coil transmits an EM field inducing eddy current loops in the ground, which in turn generate a secondary EM field that is measured by the receiver coil. The EM field measured by the receiver is comprised of both the field generated by the transmitter and the secondary field. The measured field is broken into the in-phase and quadrature components by the instrument. The in-phase component includes the primary field generated by the transmitter combined with the portion of the secondary field that has the same phase as the primary field. The quadrature component is the portion of the measured field that is 90 degrees out of phase with the primary field and is used to measure terrain conductivity. Measurements were taken at six-foot increments along survey lines six feet apart. To accomplish this spacing, grids were established using measuring tapes oriented parallel to the long dimension of the park. The playgroimd and a recently installed fence had to be avoided because of interference during the survey.

*Electrical Imaging (EI) Survey*

An Iris Instmments™ Syscal Pro, Switch 48 system was used to measure the electrical resistivity of the subsurface. An EI survey was conducted to determine the thickness of the fill along profiles at the site. An electrical current was created in the subsurface by applying a voltage through a pair of electrodes inserted in the ground. The resulting current was measured using another pair of electrodes. Using Ohm's Law, the resistance of the earth can be fomid. The equipment automatically cycles through the electrode pairs along the survey line. Resistivity depends upon the bulk properties and geometry of the material; resistivity is measiured in Ohm-meters.

Currents are carried through earth materials by the motion of the ions in the interstitial water. Ions in the water come from the dissociation of salts and provide for the flow of electric current. Resistivity decreases in water-bearing rocks and in earth materials with increasing fractional volume of the rock occupied by water, salinity of the water, permeability of the pore spaces, and temperature. Materials that lack pore space (*i.e.*, limestone, igneous rocks) or lack water in the pore space will show high resistivity.

Using the measurements collected at the site, a forward modeling subroutine was used to calculate apparent resistivity. The processing software divides the subsurface into a number of rectangular blocks. Apparent resistivity is calculated for each block resulting in a resistivity cross-section, and a number of iterations are performed, with each iteration being compared to the actual measurements, in order to minimize the root-mean-squared error.

RESULTS AND OBSERVATIONS

*Area A (Beach)*

A terrain FDEM conductivity survey and two EI profiles were performed at the beach adjacent to the park beach (Figure 2). The beach terrain had high conductivity values, exceeding 100 millimhos per meter (mmho/m), nearest to the bay and trended toward lower values about a quarter of the way up the beach (50 to 100 mmho/m). Farther up the beach the terrain conductivity was somewhat uniform with conductivity readings still at high levels (20 to 50 nmmho/m). An area of lower terrain conductivity occiurs in the southwestem area of the beach. Two manhole covers and a portion of the fence around the beach caused interference with the instmment; these features are labeled on Figure 2. A linear feature of low terrain conductivity crosses the southem end of the beach and lines up with the westem manhole. This feature is most likely associated with a subsurface utility.

EI Profile 1 crosses the southem portion of the beach and Profile 2 mns from the southem end of the beach northeast and extends into Area B (Figure 2). These two profiles are depicted on Figure 5. Both profiles show an area of high electrical resistivity at the surface typically extending to a depth of approximately 10 feet. Both profiles also have an area of low resistivity in the lower center area of the profile.

Terrain conductivity values greater than 20 are anomalous and could be a result of the high iron content of the slag. The resistivity values near the surface could be due to large void spaces between boulders and slag presumed to be used as fill. Area A appears to have a ten-foot layer of slag-rich fill. However, saltwater intrusion may also be contributing to the high terrain conductivity.

*Area B (Playground)*

A terrain FDEM conductivity survey was performed within the playground area designated as Area B (Figure 3). Area B has regions of both high and low terrain conductivity. The westem area, toward the beach, and the southem area extending eastward from the beach has high conductivity (exceeding 20 mmho/m). The northem area extending from near the middle of the playground eastward has low terrain conductivity (< 20 mmho/m). The playground itself was not surveyed due to the interference from the metal stmctures. This interference is apparent aromnd the perimeter of the playground, as well as at a large metal pole southwest of the playground. A linear feature to each side of the pole suggests that a subsurface utility may pass through the area.

Two EI profiles were performed in Area B and shown in Figure 5. EI Profile 3 crosses the area just north of the playground and Profile 4 is perpendicular to Profile 3 and is east of the playground. Profile 2 extends from Area A into the northwest comer of Area B. The high resistive layer near the surface is not as continuous in Profile 3 as it is in Profile 1 and 2; however, where it does occur, it is thicker, exceeding 20 feet in some places. This layer only occurs in about half of the length of Profile 4 where it is also discontinuous. This layer is approximately 10 feet thick in the portion of Profile 2 that extends into this area. Both Profiles 3 and 4 have large areas of low resistive material in the subsurface.

GPR Profile 3 extends from Area C, where 3 profiles were collected, across 180 feet of Area B mnning along the southem portion of the investigated area. The profile shows the typical response of fill material with a strong shallow reflector and incoherent reflections below.

*Area C (Walkway Ared)*

A terrain FDEM conductivity survey, one EI profile and three GPR profiles were collected in the walkway area east (Area C) of the playground (Figure 4). Area C was dominated by high terrain conductivity. Terrain conductivity values exceeding 100 mmho/m were detected north of the storm water discharge at the Raritan Bay in the center of the area with values exceeding 50 mmho/m around the discharge. The area of low terrain conductivity in Area B north of the playground extends into the westem part of this area. A linear feature of low terrain conductivity mns across the northem portion of the area and an area of low terrain conductivity occurs in the center of the area as well as another on the eastem edge. This variation of low to high conductivity implies that different types of fill material were used, but that fill material with high conductivity predominates.

Three GPR profiles were collected in Area C (Figure 6). Profile 1 mns west to east in the southem portion of the area near the base of the embankment. Profile 2 mns south to north from the top of embankment. Profile 3 extends from across the southeast portion of Area C into Area B. The penetration of the radar waves was limited to two to four feet. A strong reflection at approximately two feet deep was recorded below which only chaotic reflections were received. Chaotic reflections are typical of fill material.

The two places where the GPR was operated over asphalt are apparent in Profiles 1 and 2 (Figure 6). Profile 1 traversed the storm water discharge pipe, and the resulting hyperbola is noted on the profile.

EI Profile 5 runs along the southem portion of the area parallel to and overlapping the linear feature in the terrain conductivity. The profile is dominated by the high resistive layer that is approximately 15 feet thick and reaches 20 feet thick (Figure 5). The storm water discharge pipe is also apparent near the surface in the center of the profile. The resistivity of the surface layer is as high as the void space of the discharge pipe.

## CONCLUSIONS

Approximately six acres of the Old Bridge Waterfront Park, including the beach adjacent to the park, were surveyed using FDEM, EI and GPR methods. Interpretations of the data derived from these surveys are:

1) All three areas (Areas A, B and C) are characterized by high terrain conductivity that is expected to be predominantly slag material.

2) Seawater intrusion, particularly for Area A and the stormwater outfall in Area C, may be contributing to high conductivity readings. However, this seawater intmsion is not expected to be affecting Area B and most of Area C based on the low conductivity areas that were also present in these areas. This variation of low to high conductivity implies that different types of fill material were used, but that fill material with high conductivity dominates.

3) The EI profiles for all three areas presented high electrical resistivity near the surface which is indicative of the majority of the site having a layer of fill material composed of large pieces of rock or slag with large voids.

4) Boulder-sized fill material (including potential slag) ranges from 10 to 20 feet thick with a soil covering of less than two feet.

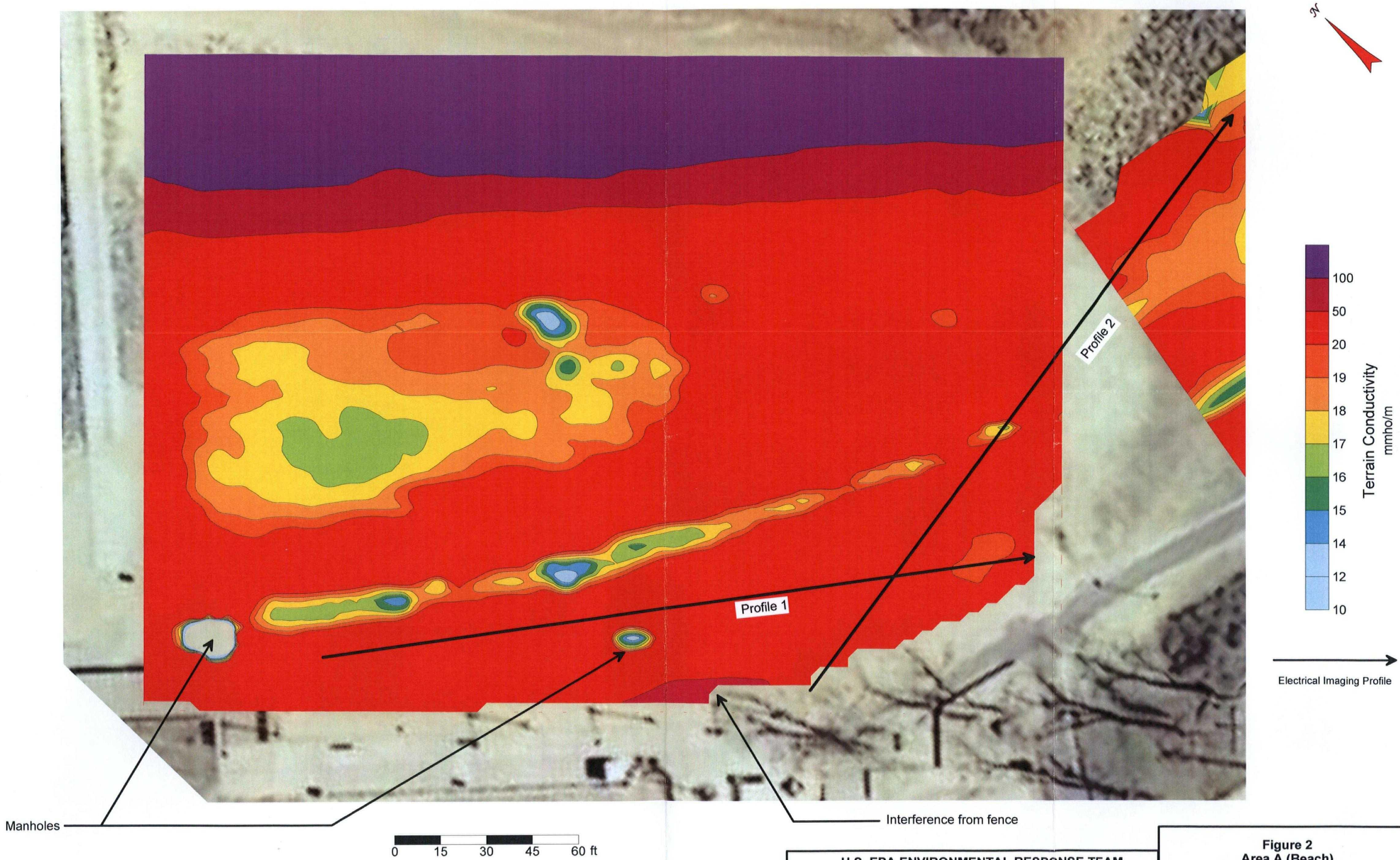
## OPTIONS FOR ADDITIONAL EVALUATIONS

It is recommended that exploratory excavations be performed to verify the geophysical interpretation. The excavations should be in areas with both high and low terrain conductivity to verify the content of the fill material (*e.g.* slag). It is also recommended that an EI profile(s) be performed in these areas prior to the excavation. This will allow a depth profile correlation between the profile and actual excavation. Once the model is refined based on correlations with the excavations, the FDEM and EI methods can be combined to estimate the volume of slag including a map of its distribution.

# Figures

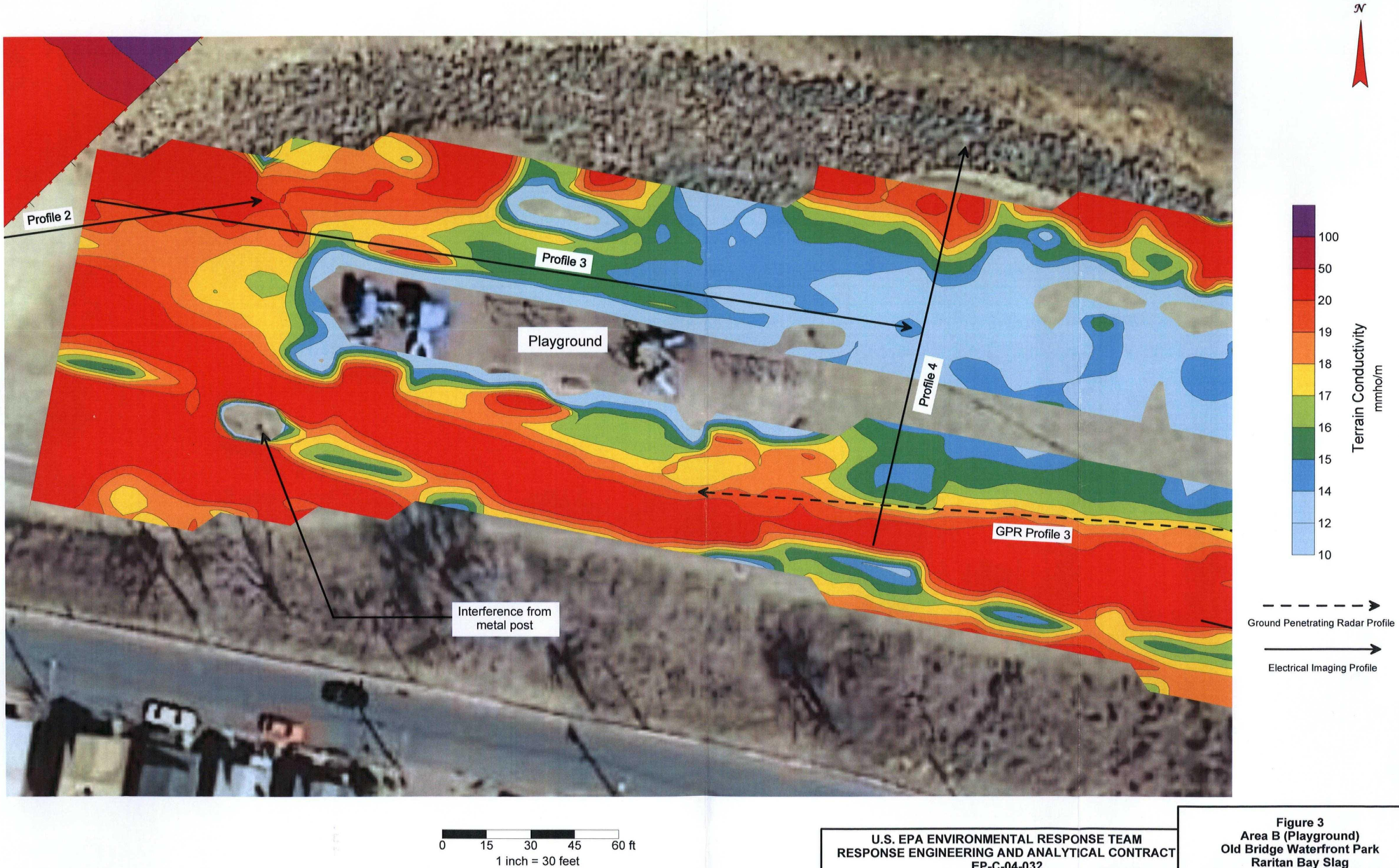

U.S. EPA ENVIRONMENTAL RESPONSE TEAM
RESPONSE ENGINEERING AND ANALYTICAL CONTRACT
EP-C-04-032
W.A.# 0-356

**Figure 1**
**Study Area**
**Old Bridge Waterfront Park**
**Raritan Bay Slag**
**Laurence Harbor, New Jersey**



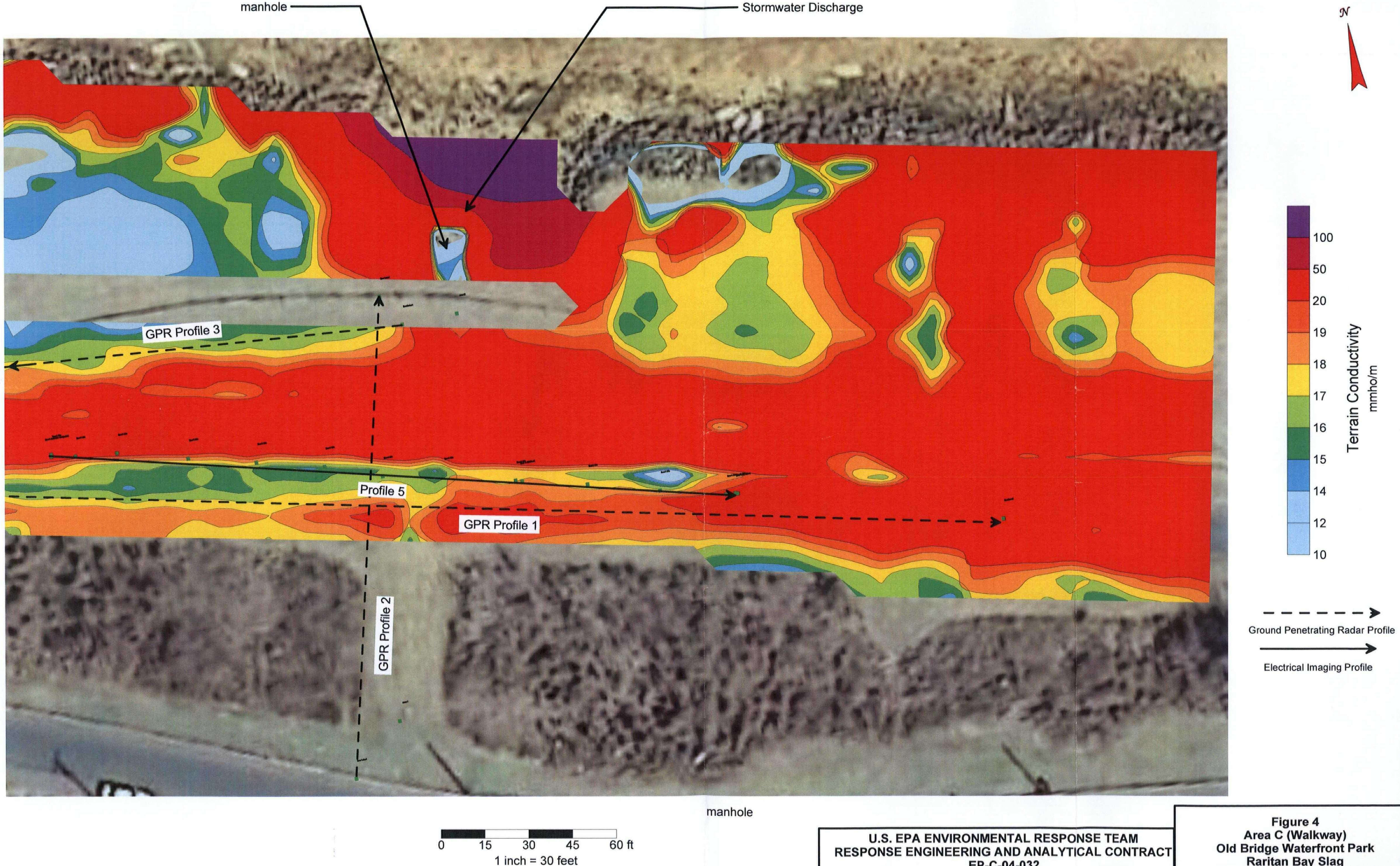

U.S. EPA ENVIRONMENTAL RESPONSE TEAM
RESPONSE ENGINEERING AND ANALYTICAL CONTRACT
EP-C-04-032
W.A.# 0-356

**Figure 2**
**Area A (Beach)**
**Old Bridge Waterfront Park**
**Raritan Bay Slag**
**Laurence Harbor, New Jersey**



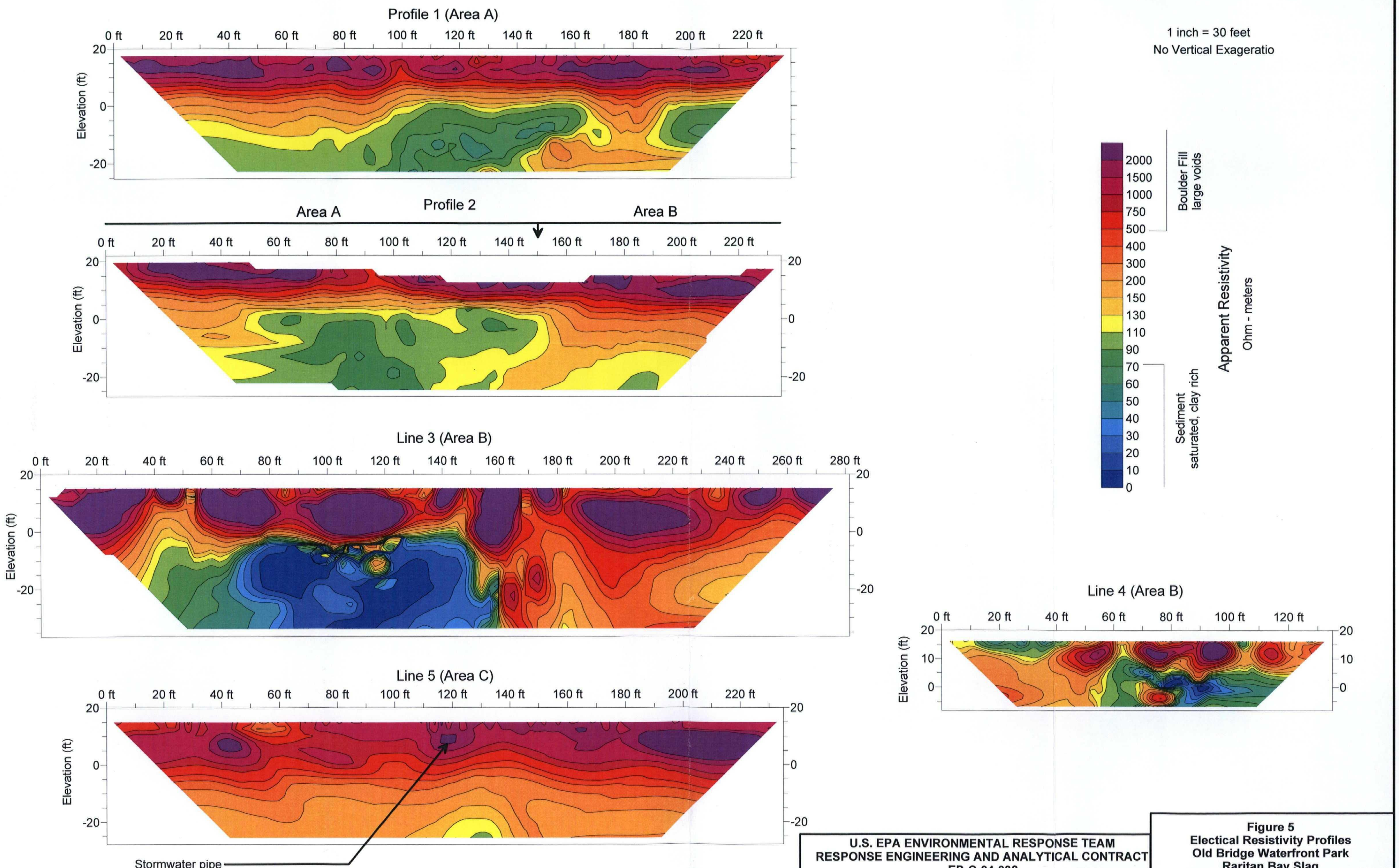

U.S. EPA ENVIRONMENTAL RESPONSE TEAM
RESPONSE ENGINEERING AND ANALYTICAL CONTRACT
EP-C-04-032
W.A.# 0-356

**Figure 3**
**Area B (Playground)**
**Old Bridge Waterfront Park**
**Raritan Bay Slag**
**Laurence Harbor, New Jersey**



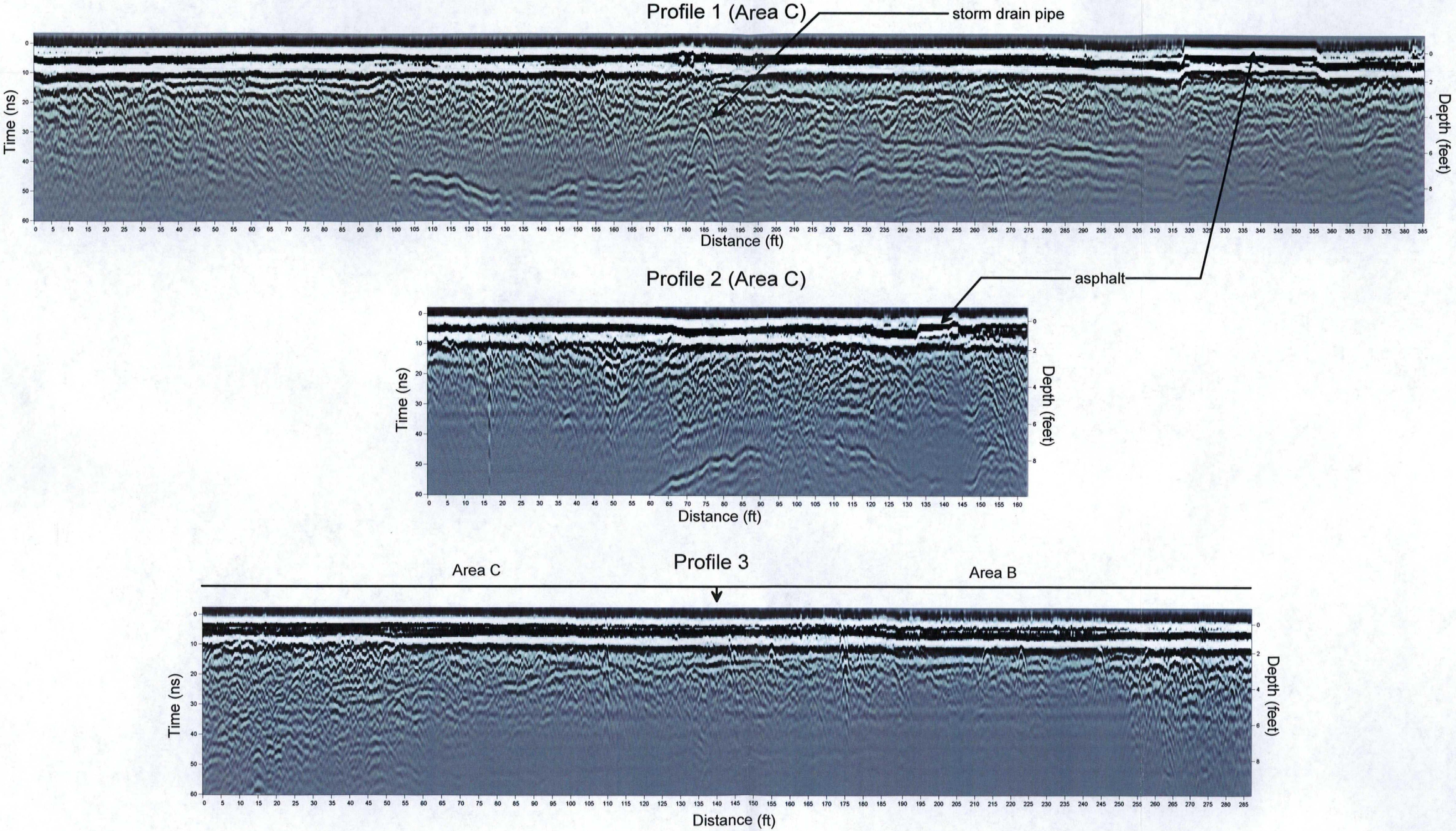

U.S. EPA ENVIRONMENTAL RESPONSE TEAM
RESPONSE ENGINEERING AND ANALYTICAL CONTRACT
EP-C-04-032
W.A.# 0-356

**Figure 4**
**Area C (Walkway)**
**Old Bridge Waterfront Park**
**Raritan Bay Slag**
**Laurence Harbor, New Jersey**




**U.S. EPA ENVIRONMENTAL RESPONSE TEAM**
**RESPONSE ENGINEERING AND ANALYTICAL CONTRACT**
**EP-C-04-032**
**W.A.# 0-356**

**Figure 5**
**Electical Resistivity Profiles**
**Old Bridge Waterfront Park**
**Raritan Bay Slag**
**Laurence Harbor, New Jersey**




U.S. EPA ENVIRONMENTAL RESPONSE TEAM
RESPONSE ENGINEERING AND ANALYTICAL CONTRACT
EP-C-04-032
W.A.# 0-356

**Figure 6**
**Ground Penetrating Radar Profiles**
**Old Bridge Waterfront Park**
**Raritan Bay Slag**
**Laurence Harbor, New Jersey**